

## Response to RC1 (reviewer comments in grey)

This article provides an assessment of decadal variability of global air-sea carbon dioxide fluxes. The authors use the LDEO-HPD, a data product, in order to evaluate the dominant modes of decadal variability of global air-sea CO<sub>2</sub> fluxes and compare regional contributions to this variability. They find strong correlations between dominant modes of decadal flux variability and strong synchronous signals between the tropical Pacific and the Southern Ocean. The overall paper article is thorough and robust in analysis. A few comments I think would improve the overall clarity and analysis:

We thank the reviewer for the positive assessment and constructive suggestions, which we address point by point below.

In figure 2, it looks like starting in 1980 when data availability increases, the variability increases as well. This is for all basins, including Atlantic and Indian. While there is a small mention of this in the paragraph starting line 275, it focuses on the components in Figure 4. Can this be addressed some? If the time period is shortened, does that impact some of the conclusions? The uncertainty is shown as 1 standard deviation—does this vary over time?

Speaking of uncertainty, some of the standard deviations seem quite large (for example, figure 5 part A shows the FCO<sub>2</sub>' to be 64, which if that were shaded, would span from a positive to a negative at multiple points. The paper makes the point that the fCO<sub>2</sub> is overwhelming the other components, which isn't necessarily the case with uncertainty taken into account during all time periods. I think the paper could be stronger with addressing some of this uncertainty in the discussion.

The reviewer is correct that variability increases after ~1980 across all basins; this is consistent with the damped pre-1982 variability we discuss at L275-280, arising from the climatological correction to the pCO<sub>2</sub> field and likely also due to sparser data going into the reanalysis forcing for the global ocean biogeochemical models before 1982. We expand the discussion to make the connection explicit.

Regarding the effect of shortening the record: we have looked at the 90s and the 2000s in isolation, and found similar results in the EOF and PC results. However, we elect to focus on the full period available in the LDEO-HPD product to look at the decadal variability. The central contribution of this study is that the extended 66-year LDEO-HPD record resolves more than a full period of decadal variability, placing the previously-reported 1980s to 2000s changes in a longer-term context for the first time. We will add to the text noting that the conclusions pertain to the full record and that the added early decades are what reveal the multi-decadal behavior.

We'd like to clarify that the reported 1 $\sigma$  values represent the amplitude of decadal variability rather than an uncertainty envelope. We clarify this in the caption to the figure.

Additionally, there are several points in the paper where the reader is asked to compare two different figures, that are often on different axes and different formats. For example, line 304 the comparison of Figure 7 to Figure 6 (left column) left me a little confused about if I was comparing the right things and flipping across multiple pages. While this can sometimes happen, I think it

would be nice if a few figures were adjusted with either an overlay or some alternate method of easier comparison within one figure.

We thank the reviewer for the suggestion to improve figure placements. We combined Figure 7 into Figure 6 to allow for easier comparisons.

**Line-level edits:**

In both the abstract and the Introduction, the statement is made that the ocean carbon sink has “mitigated climate change”. While the ocean carbon sink is playing a mitigating role in the impacts of climate change, the sentence reads in a way that implies it has successfully mitigated climate change completely, which is false. I suggest a slight reword to suggest that while it does act as a mitigator on climate change, it has not successfully mitigated climate change.

We thank the reviewer for the wording adjustment. We reworded the abstract and introduction text to state that the ocean sink plays a mitigating role rather than having mitigated climate change.

In equation (1), the gas transfer velocity is used. Although details can be looked up in Bennington et al., due to the nature of importance of this selection a quick reference on choice of coefficient for  $k$  might be helpful to include here.

We have included details about the gas-transfer coefficient choice in the text describing Eq. 1.

Figure 4 is a little confusing—the bottom row of line plots don’t seem to have associated letters, and I assume the colors match but I think some adjustment in titles, figure letters, etc would be helpful to increase clarity

Figure 6 has an inserted graph with no axis labels/units.

We thank the reviewer for their figure improvement suggestions. We made all their suggested changes. We added figure panel lettering and adjusted panel titles to improve the clarity of Figure 4. Figure 6 now has Figure 7 combined into it, so the old inset graph is no longer be there.

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